VUF-1031
FINAL REPORT

VELA UNIFORM PROGRAM

PROJECT DRIBBLE

SALMON EVENT

TATUM SALT DOME, MISSISSIPPI

22 OCTOBER 1964

part of an experiment in seismic decoupling at the nuclear level

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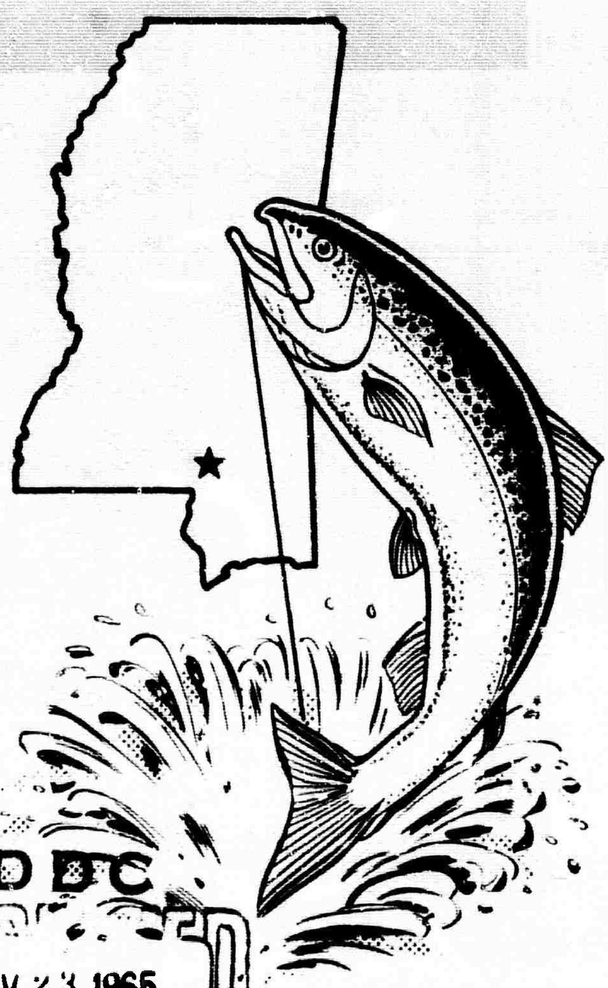

Structural Response of Tall Industrial and Residential Structures to an Underground Nuclear Detonation

JOHN A. BLUME AND ASSOCIATES
RESEARCH DIVISION

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SALMON EVENT

PROJECT DRIBBLE

STRUCTURAL RESPONSE OF TALL INDUSTRIAL AND RESIDENTIAL STRUCTURES TO AN UNDERGROUND NUCLEAR DETONATION

John A. Blume & Associates Research Division

August 1965

CONTENTS

ABSTRACT

Two tall refinery structures and an eight-story University women's dormitory structure were instrumented for measurement of response to ground motion generated by the Salmon event. The refinery is about 18 kilometers from Surface Zero; the dormitory is about 30.6 kilometers. NGS 19L velocity meters were deployed at several levels on the refinery structures, and Sprengnether portable displacement meters were used on the top and bottom floors of the dormitory.

Measured peak top level velocities in the two refinery structures were 7.31 centimeters per second in the taller TCC structure and 5.6 centimeters per second in the DIB tower, at periods of 0.19 seconds and 0.20 seconds respectively. Peak top floor displacement in the dormitory was 0.15 centimeters with a period of about 0.43 seconds.

Blume observers reported a clearly perceptible motion in the dormitory, felt by uninformed persons on bottom and top floors. No official observers were present at the refinery but personnel working there also reported clearly perceptible motion.

INTRODUCTION

OBJECTIVES

This report is concerned with the investigation of structural response of three tall structures near Hattiesburg, Mississippi. In pursuance of a structural response investigation, personnel from this office were present in Hattiesburg as observers for an underground nuclear detonation, the Salmon event, Project Dribble. As part of these observations, two tall refinery structures at the Mississippi-Gulf Refinery near Purvis, Mississippi, and the women's dormitory at the University of Southern Mississippi in Hattiesburg were instrumented to record their response to the ground motion resulting from the Salmon event.

Data obtained from the Salmon event are summarized in this report. Analysis of structural response is limited to a presentation of the general geometries and physical characteristics of the buildings concerned and a brief consideration of the anticipated response and that response which was actually measured. Further study of the response of these structures may be accomplished at an appropriate point in the development of the general structural response investigation for which this firm is under contract to the United States Atomic Energy Commission.

BACKGROUND

The Salmon event involved a 5-kiloton device in a tamped emplacement at the bottom of a bore hole about 825 meters deep. The device was located approximately 365 meters into the Tatum Salt Dome in Lamar County near Baxterville, Mississippi, and was detonated at 1600 hours, Greenwich Time, on October 22, 1964.

Structures at the Mississippi-Gulf Refinery are at a distance of approximately 18.0 kilometers from Surface Zero; the women's dormitory at the University of Southern Mississippi is approximately 30.8 kilometers from Surface Zero (ground surface location of the top of the bore hole in which the device was located). Figure 1 shows the location of these structures with reference to ground zero for the Salmon event. Structural information for these buildings is given in English units.

STRUCTURES AND FOUNDATION SOILS

The women's dormitory at the University of Southern Mississippi as shown in Figure 2 is a modern eight-story concrete frame structure with 5-1/2-inch concrete slab floors. The structure is founded on short piling. The 10-inch thick exterior walls are composed of 2-inch to 4-inch masonry panels of brick and concrete block or cast stone panels and concrete block. The majority of the interior walls are 4-inch concrete block. Two transverse expansion joints divide the building into three separate structural elements.

Instrumentation for the dormitory was in the center element; the weight of this portion of the building is approximately 4,700 kips (kip equals 1,000 pounds). The outside portions weigh approximately 4,000 kips each. Weight of each portion is fairly uniformly distributed over its height.

Soils underlying the dormitory are mainly alternating layers of firm silt and stiff clay. Compressional wave velocities for these soils were measured, using a portable seismograph, and were found to vary from 300 meters per second for near surface layers to 900 meters per second at depth.

The GV-2 Deisobutanizer (DIB) at the Mississippi-Gulf Refinery is a cylindrical shell structure 150 feet high and 8 feet in diameter as shown in Figure 3. The major portion of the shell is 5/8-inch steel plate covered with 2-3/4 inches of insulation. Total weight of the sheel is about 100 kips. Operating weight is about 285 kips.

The interior of the Deisobutanizer is filled with a series of trays spaced at approximately 2 feet vertically throughout the entire height. The foundation is a reinforced concrete mat.

Soils in the vicinity of the Mississippi-Gulf Refinery are mainly alternating layers of firm silt and stiff clay. A few sandy silts were noted in road cuts. Compressional wave velocities vary from 440 meters per second to 730 meters per second for near surface material. Underlying the 730 meters per second is a 300 meters per second layer of unknown depth.

The catalyst cracker (TCC) at the Mississippi-Gulf Refinery is a steel frame structure 40 feet square in plan and 254 feet high, with a superstructure extending to 297 feet as shown in Figure 3. Except for the diagonals, which are composed of two angles back to back, the framing consists of steel wide flange members. Columns are fireproofed with concrete for the first 50 feet, and with "Hylag" lightweight fireproofing for 60 feet beyond the concrete. The columns vary in size from 14WF320 with 18-inch by 1-1/4-inch cover plates at the base to 14WF61 with no cover plates at the top. Total weight of the structure including the large vessels is approximately 1,400 kips with the vessels empty and 2,500 kips with the vessels full. The foundation is a reinforced mat.

PROCEDURE

INSTRUMENTATION

Two Sprengnether portable seismographs were manned by John A. Blume & Associates Research Division personnel to record displacement at the top and bottom of the center section of the women's dormitory building. The instrument arrangement is shown in Figure 4.

Each of these instruments simultaneously records vibratory displacement in three mutually perpendicular directions as a function of time. The instrumental characteristics for each Sprengnether are given in Figure 6.

The instruments were started simultaneously at shot time by means of a common manual remote control. Shot time was determined from the shortwave broadcasts from the Salmon Central Control Station.

Original records consist of long paper traces which cannot be reproduced in a form suitable for inclusion in this report.

The National Geophysical Company under the direction of the United States Coast and Geodetic Survey manned 35 channels of NGS 19L velocity meter information at the Mississippi-Gulf Refinery. The velocity pickups were located and oriented on the TCC and DIB structures as shown in Figure 5. Deployment of the instruments was designed by John A. Blume & Associates Research Division.

The NGS 19L system consists of a number of portable velocity pickups. Both horizontal and vertical velocity meters were employed. The pickup voltage outputs are brought to an amplifying and recording system. The information from all the pickups is recorded simultaneously, as a function of time, on a strip of photosensitive paper. For the Salmon event the WWV radio time signals were also included on the records to provide accurate shot time correlation.

Because of the large quantity of velocity pickups employed, two recording systems were required. Instrument characteristics are shown in Figure 6.

PERCEPTION OBSERVERS

John A. Blume & Associates Research Division observers were stationed on the roof of the women's dormitory and inside at the top of the stairwell (see Figure 5). At shot time the observer on the roof stood with his back against the stairwell wall and sighted along the wall aligning the corner of the stairwell with another structure about 1/2 mile away. The other observer knelt inside the stairwell with one shoulder against the wall.

No observers from John A. Blume & Associates Research Division were present at the Mississippi-Gulf Refinery at time of shot. Pre-shot investigations were made, and a representative visited the refinery about 3 hours after the disturbance.

RESULTS

RECORDED MOTION

A preliminary visual examination of the records from the dormitory, TCC and DIB structures has yielded the data given in Tables 1 and 2. No attempt has as yet been made by this office to analyze these records with computer programs; however, an analysis of Salmon ground motion records was made by R. F. Beers, Inc., and is discussed in their report NVO-1163-51 dated April 1, 1965.

The amplitudes shown were obtained by measuring the maximum average double amplitude on the trace and taking half of this as the single amplitude. Care was taken to keep the effect of the amplitude conversion factor variation with period of motion in mind so that an apparent maximum amplitude could be rejected in favor of a lesser trace amplitude whose conversion factor may produce a greater actual displacement, velocity, or acceleration.

The trace amplitudes were converted to actual motion by use of the instrument characteristics given in Figure 6.

The actual displacement, velocity, or acceleration from each instrument were converted to the other measures of motion by assuming simple harmonic motion.

It should be noted that the majority of the instruments from which these values were derived respond only to motion in a limited period range. Hence, important response may have been missed. One case in point is the NGS 19L record from the TCC structure at the Mississippi-Gulf Refinery. The pre-shot record taken with a Sprengnether seismograph recorded large amplitude background motion with a period of about 1.3 seconds. Theoretical calculations using several different methods have indicated that the first mode of translational vibration should be about 1.3 seconds. However, there is no visually perceptible 1.3-second prior motion on the NGS 19L record for the TCC structure. It seems probable that 1.3-second motion occurred during the Salmon disturbance at the top of the TCC structure. However, for it to have been perceptible on the record would require that it have a velocity of about 13 centimeters per second. The maximum visible velocity on the record is about 6.5 centimeters per second. Consequently, we assume that the instrument characteristics filtered out the fundamental period motion at 1.3 seconds.

Whenever data from Tables 1 to 3 are used, the instrument response characteristics must be considered.

PERCEPTION REPORTS

Weak motion began in the women's dormitory about 10 to 12 seconds after detonation time. Within a second the disturbance was producing very strong motion which peaked fairly rapidly and lessened slightly to a level which lasted for about 20 seconds (this would be about 30 seconds after detonation). Motion was perceptible for more than 60 seconds after shot time.

Motion felt elliptical in the horizontal plane. Ratio of transverse to longitudinal motion seemed about 4 to 1. Vertical motion was barely perceptible.

The roof observer believed he could visually detect motion along his sight line but it was so slight that he could give no magnitude to it. The interior observer was able to sense transverse oscillations and estimated a period of about 0.5 seconds with his wrist watch.

Many dormitory residents were startled by the motion. Most, if not all, were unaware of the proposed detonation time. The dormitory matron who was standing at the ground floor reception desk was also startled by the motion. She, too, was not aware of the shot time.

Many employees of the Mississippi-Gulf Refinery were aware of the proposed detonation time. The disturbance was reported to be easily felt. Automobiles in the parking lot rocked considerably. A group of office workers placed a glass of water in the sunlight on the floor and estimated that the light reflection on the approximately 10-foot high ceiling moved about 27 inches before the water turbulence disrupted the reflection.

Several "Tilt Alarms" on the refinery structures were set off during the Salmon disturbance. However, the refinery engineer was hesitant to give much significance to this because of alarm device inaccuracy and the uncertainty of pre-shot degree of structure tilt.

DISCUSSION

STRUCTURAL RESPONSE

An analysis of the catalyst cracker (TCC) for natural periods of vibration gave the following results:

T_1 = 1.3 seconds

T_2 = 0.56 seconds

T_3 = 0.42 seconds

T_4 = 0.26 seconds

A 10-mass system was used for this analysis except for the third mode period calculation which used a 4-mass system. Stiffness factor calculations assumed pinned connections. The value for the first mode period, 1.3 seconds, agrees well with that from a Sprengnether seismograph record of background TCC motion. The predominant period on the velocity record is approximately 0.26 seconds, as obtained from velocity meter records. This would be approximately the period of the fourth mode.

The velocity record taken on the DIB tower during the event shows a predominant period of approximately 0.20 seconds. Assuming the tower is a vertical uniform cantilever beam gives a calculated first mode period of 0.45 seconds. On the basis of this rough calculation, the Deisobutanizer may have been vibrating in the second mode. A measure of damping in the structure was obtained using a section of the record near the end, where the motion of the structure was periodic with a rapidly decreasing amplitude. Ground motion was greatly diminished this late in the record. The calculated damping value is about 5 percent of critical damping.

The fundamental period of the central portion of the women's dormitory is calculated to be approximately 0.45 seconds in the longitudinal direction (north-south) and 0.47 seconds in the transverse direction (east-west). The period of the central portion of the dormitory building is approximately 0.45 seconds in the north-south direction. The velocity record obtained during the event shows predominant periods of approximately 0.56 seconds in the north-south direction and 0.43 seconds in the east-west direction, suggesting that the building was vibrating in the first mode during the event. Deflection calculations, assuming frame action only and using maximum ground acceleration times the mass of the building as the applied force, indicate that block partition walls were acting structurally during the event

HUMAN PERCEPTION

Data from perception observations in Las Vegas indicate that a threshold of clear motion perception at a frequency of 2 to 2-1/2 cycles per second (measured in the women's dormitory) would be about 0.004 g (gravity units). Calculated peak acceleration in the women's dormitory is 0.032 g on the top floor, well above the 0.004 g threshold.

Although top floor motions in the dormitory were sufficiently close to simple harmonic motion to permit a reliable calculation of acceleration from measured displacements, this situation is not true for ground motions. Measured ground accelerations are not available for either the dormitory or the refinery. The motion was clearly felt at both locations and accelerations were undoubtedly well above 0.004 g.

CONCLUSIONS AND RECOMMENDATIONS

Instrumentation in tall industrial and residential structures in the Dribble Project area was adequate to record peak motions in high-rise structures. Response of these structures was below damage thresholds. Consequently, the primary objective of this aspect, to monitor and record response of this type of structure, achieved. Instrumentation of similar structures for future off-site events is recommended, both because of the great value of such data to structural response investigations and also because of the inherently greater damage potential in tall buildings from enhanced structural response and because of the greater financial investment represented.

Reduction of the records for digital computer processing, if deemed necessary, would have been difficult and tedious, particularly for the low-speed, high-sensitivity Sprengnether on the ground floor of the women's dormitory, and for the lengthy NGS 19L records. Recently acquired Sprengnether instruments have higher speeds and lower sensitivities, and records from these instruments are proving to be satisfactory for any digitizing which may be required. Also, the NGS 21 velocity meters, which will be used in place of the NGS 19L instruments, are largely equipped for magnetic tape recording which can be more readily digitized.

The motion generated by the Salmon event was clearly perceptible in the women's dormitory at all floor levels, as well as at the Mississippi-Gulf Refinery and elsewhere throughout the area. It seems likely that there is some subjective correlation between this very clear perception of motion and the high incidence of damage claims which ensued. In future events off site, particularly in non-seismic areas, we recommend a program of public education even more active than that employed prior to the Salmon event to provide forewarning of event motion and to attempt to minimize the surprise element attending unexpectedly clear perception of motion.

SUMMARY OF PEAK MOTIONS

			DISPLACEMENT IN	DISPLACEMENT C.M.	T	VELOCITY IN/SEC	VELOCITY C.M./SEC.	T	ACCELERATION g	T
U.S.M. DORM TOP SPRENGNETHER #1650	L	N/S	0.05	0.13	0.56	0.50 *	1.27	0.56	0.015 *	0.56
	T	E/W	0.06	0.15	0.43	0.80 *	2.03	0.43	0.032 *	0.43
	V		0.02	0.05	0.42	0.30 *	0.76	0.42	0.010 *	0.42
U.S.M. DORM BOTTOM SPRENGNETHER #1532	L	N/S	0.006	0.015	0.60	0.066 *	0.167	0.60	0.002 *	0.60
	T	E/W	0.01	0.025	0.40	0.17 *	0.43	0.40	0.006 *	0.40
	V		0.01	0.025	0.34	0.21 *	0.53	0.34	0.010 *	0.34

* THESE VALUES ARE DERIVED, ASSUMING SIMPLE HARMONIC MOTION. OTHERS MEASURED.
JOHN A. BLUME & ASSOCIATES - RESEARCH DIVISION

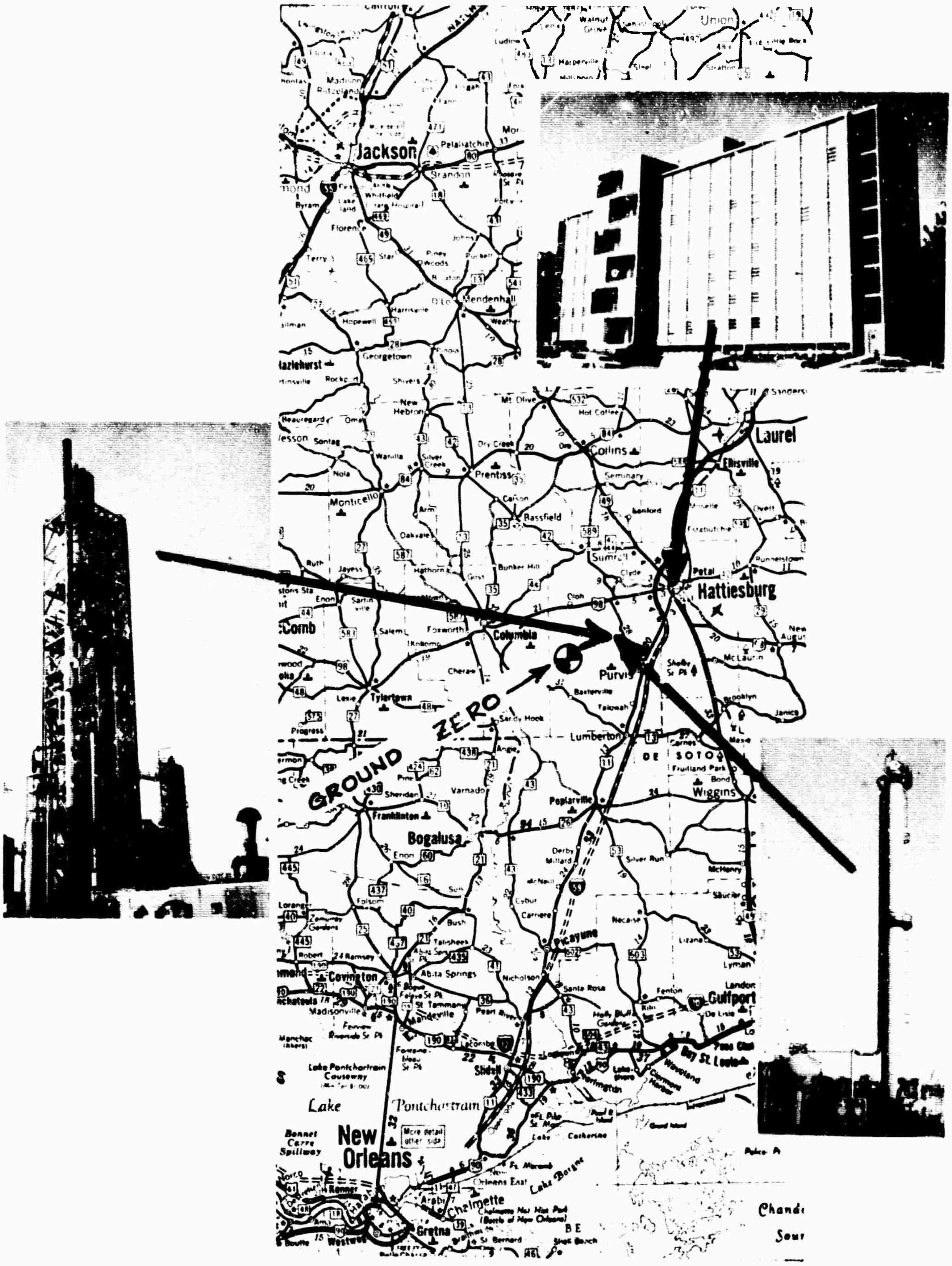
TABLE 1

SUMMARY OF PEAK MOTIONS

			Displacement IN.	Displacement CM.	T	Velocity IN./SEC.	Velocity CM./SEC.	T	ACCELERATION	T
T.C.C. BKGRND. SPRENGNETHER #1650 MAX. LONG PERIOD	T	N/S	0.011	0.03	1.30	0.05 *	0.13	1.30	0.0007 *	1.30
MAX. SHORT PERIOD	T	N/S	0.005	0.013	0.26	0.13 *	0.33	0.26	0.010 *	0.26
T.C.C. TOP NGC 19	R	E/W	0.057 *	0.144	0.18	1.98	5.00	0.18	0.180 *	0.18
	T	N/S	0.03 *	0.076	0.26	0.72	1.82	0.26	0.046 *	0.26
	V		0.087 *	0.22	0.19	2.88	7.31	0.19	0.25 *	0.19
T.C.C. BOTTOM NGC 19	R	E/W	0.006 *	0.015	0.15	0.24	0.61	0.15	0.029 *	0.15
	T	N/S	0.021 *	0.053	0.25	0.52	1.32	0.25	0.035 *	0.25
	V		0.049 *	0.124	0.24	1.27	3.22	0.24	0.091 *	0.24
DIB TOP NGC 19	R				NO	TRACE	AMP.			
	T		0.07 *	0.18	0.20	2.2	5.6	0.20	0.18 *	0.20
	V		0.05 *	0.13	0.16	2.13	5.4	0.16	0.243 *	0.16
DIB BOTTOM NGC 19	R		0.01 *	0.025	0.18	0.3	0.76	0.18	0.029 *	0.18
	T		0.02 *	0.05	0.25	0.5	1.27	0.25	0.031 *	0.25
	V		0.033 *	0.08	0.17	1.2	3.05	0.17	0.130 *	0.17
DIB 900' AWAY NGC 19	R		0.011 *	0.028	0.19	0.36	0.91	0.19	0.032 *	0.19
	T		0.012 *	0.030	0.27	0.27	0.69	0.27	0.016 *	0.27
	V		0.024 *	0.060	0.24	0.63	1.60	0.24	0.044 *	0.24

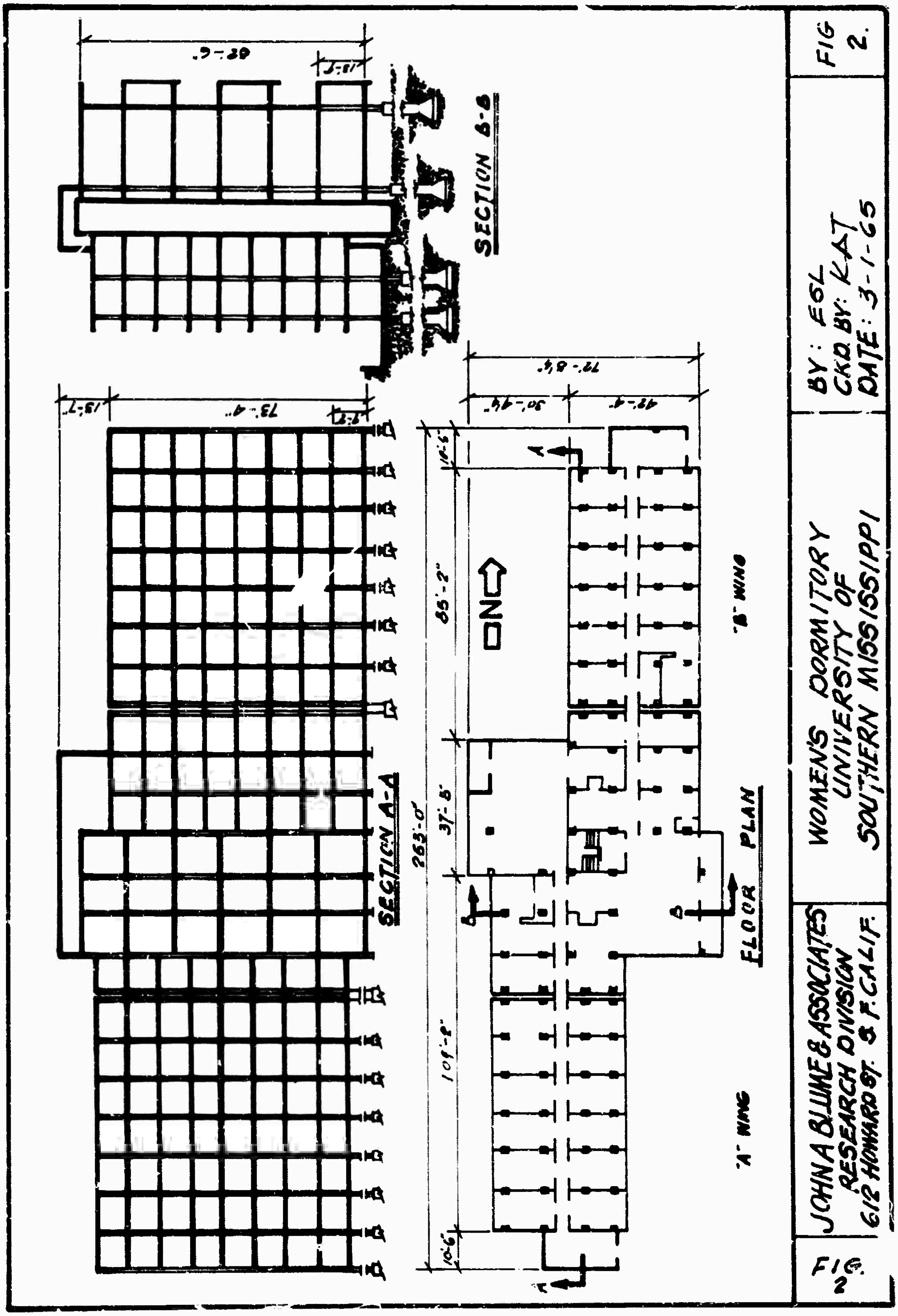
TABLE 2 *SEE TABLE 1

JOHN A. BLUME & ASSOCIATES RESEARCH DIVISION



SALMON LOCATION MAP

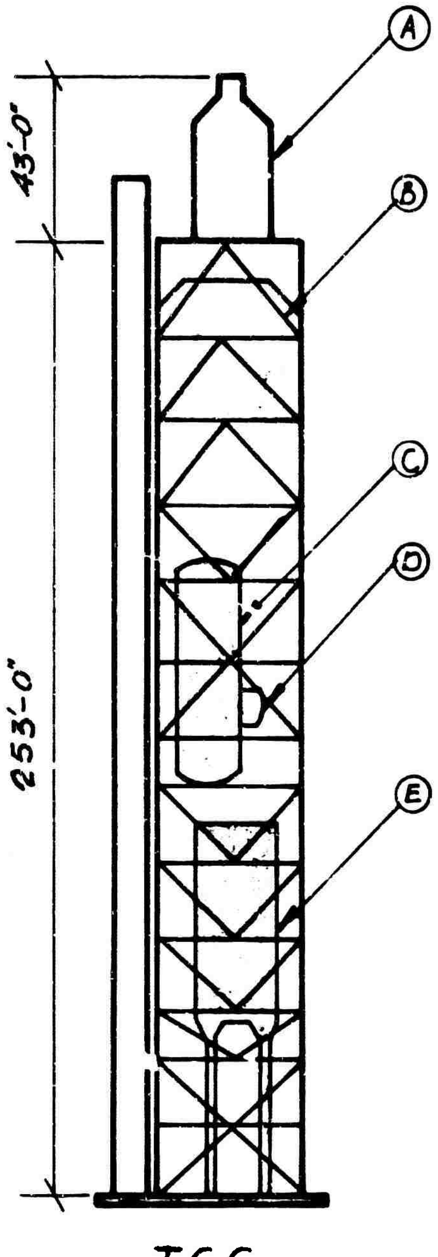
JOHN A. BLUME & ASSOCIATES RESEARCH DIVISION FIG. 1



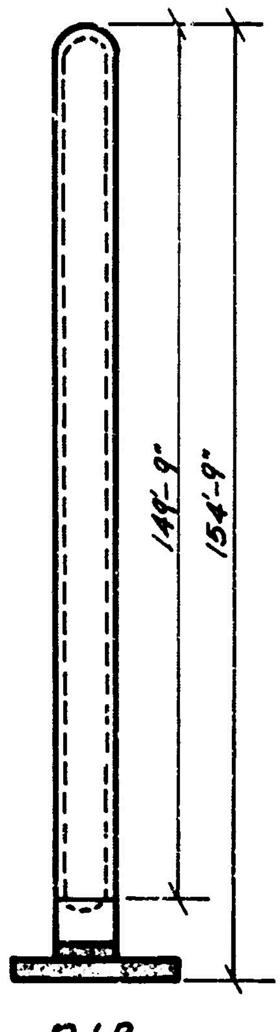
SECTION B-B
62'-6"
SECTION A-A
73'-4"
15'-7"
FLOOR PLAN
263'-0"
85'-2"
37'-8"
109'-8"
10'-6"
72'-8½"
30'-4½"
42'-4"
'A' WING
'B' WING
WOMEN'S DORMITORY
UNIVERSITY OF
SOUTHERN MISSISSIPPI
JOHN A BLUME & ASSOCIATES
RESEARCH DIVISION
612 HOWARD ST. S.F. CALIF.
BY: EGL
CKD BY: KAT
DATE: 3-1-65
FIG 2.

PRESSURE VESSEL WEIGHTS

VESSEL	WEIGHT (KIPS) DRY	WET
A	104	217
B	55	477
C	171	445
D	55	55
E	400	686

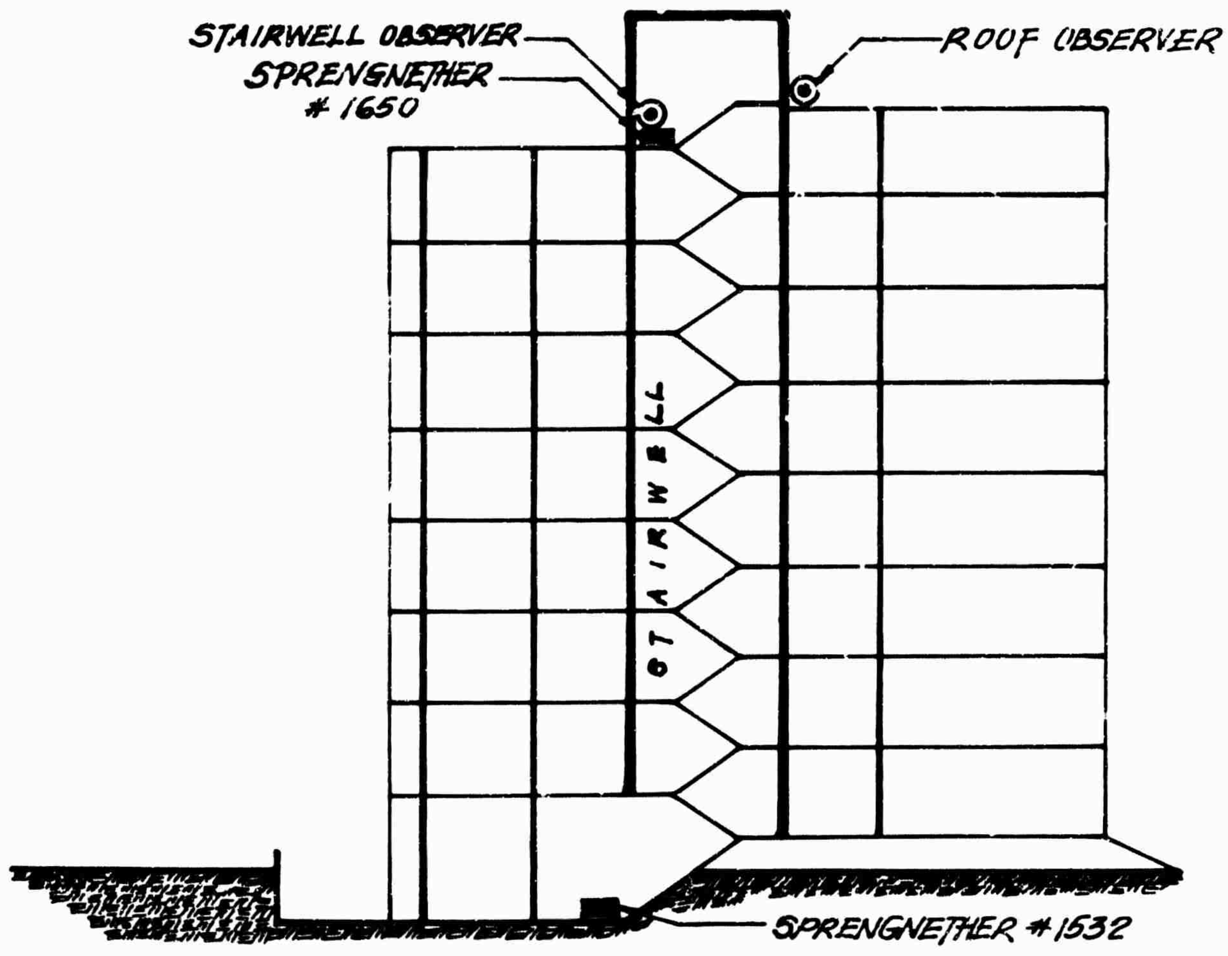


TCC
SOUTH ELEVATION
1"=50'-0"



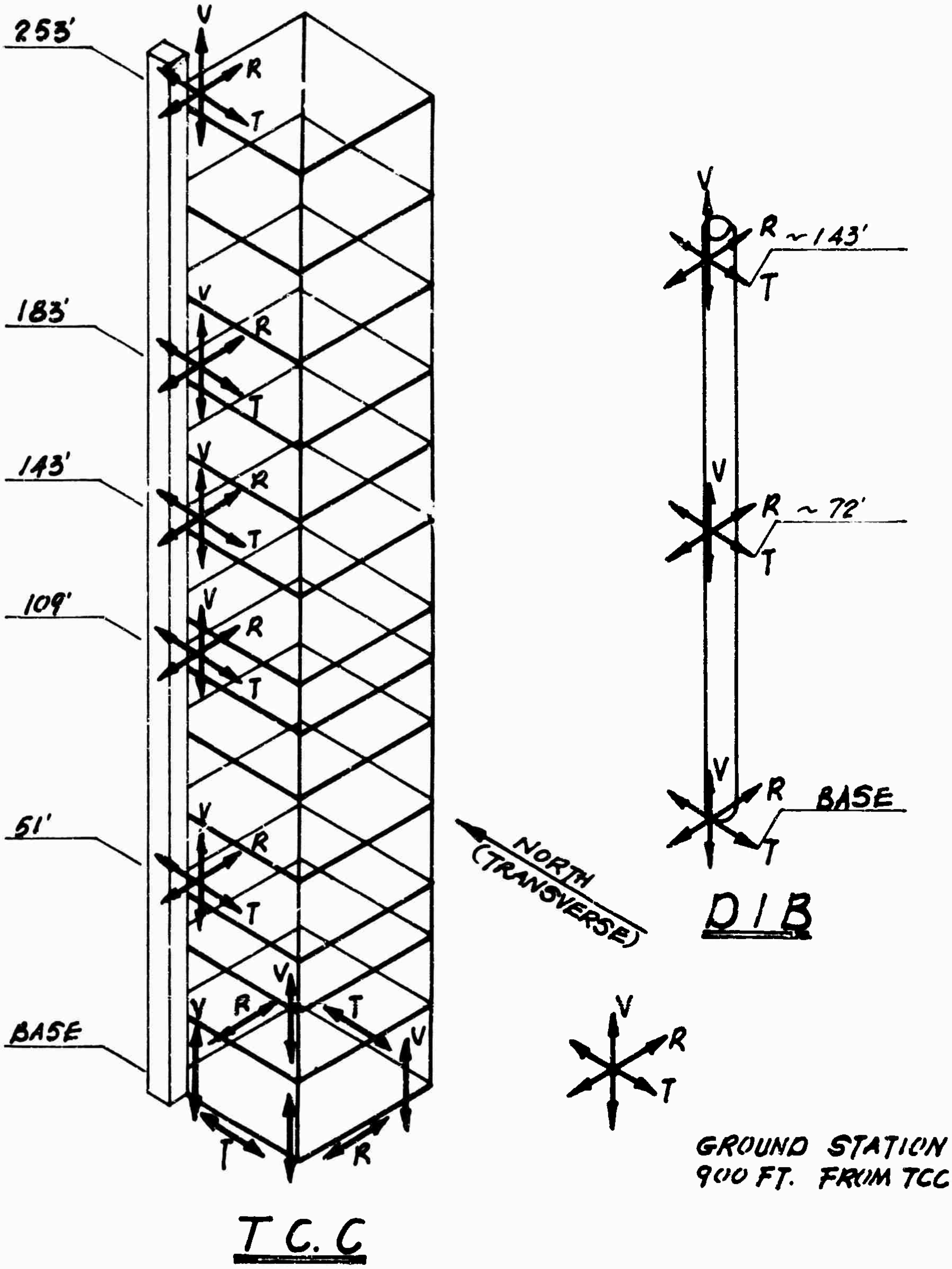
DIB
SOUTH ELEVATION
1"=30'-0"

JOHN A BLUME & ASSOCIATES RESEARCH DIVISION 612 HOWARD ST. S.F. CALIF.	TCC & DIB MISSISSIPPI GULF REFINERY STRUCTURAL ARRANGEMENT	BY: ESL CKD.BY: KAT DATE: 3-1-65	FIG 3

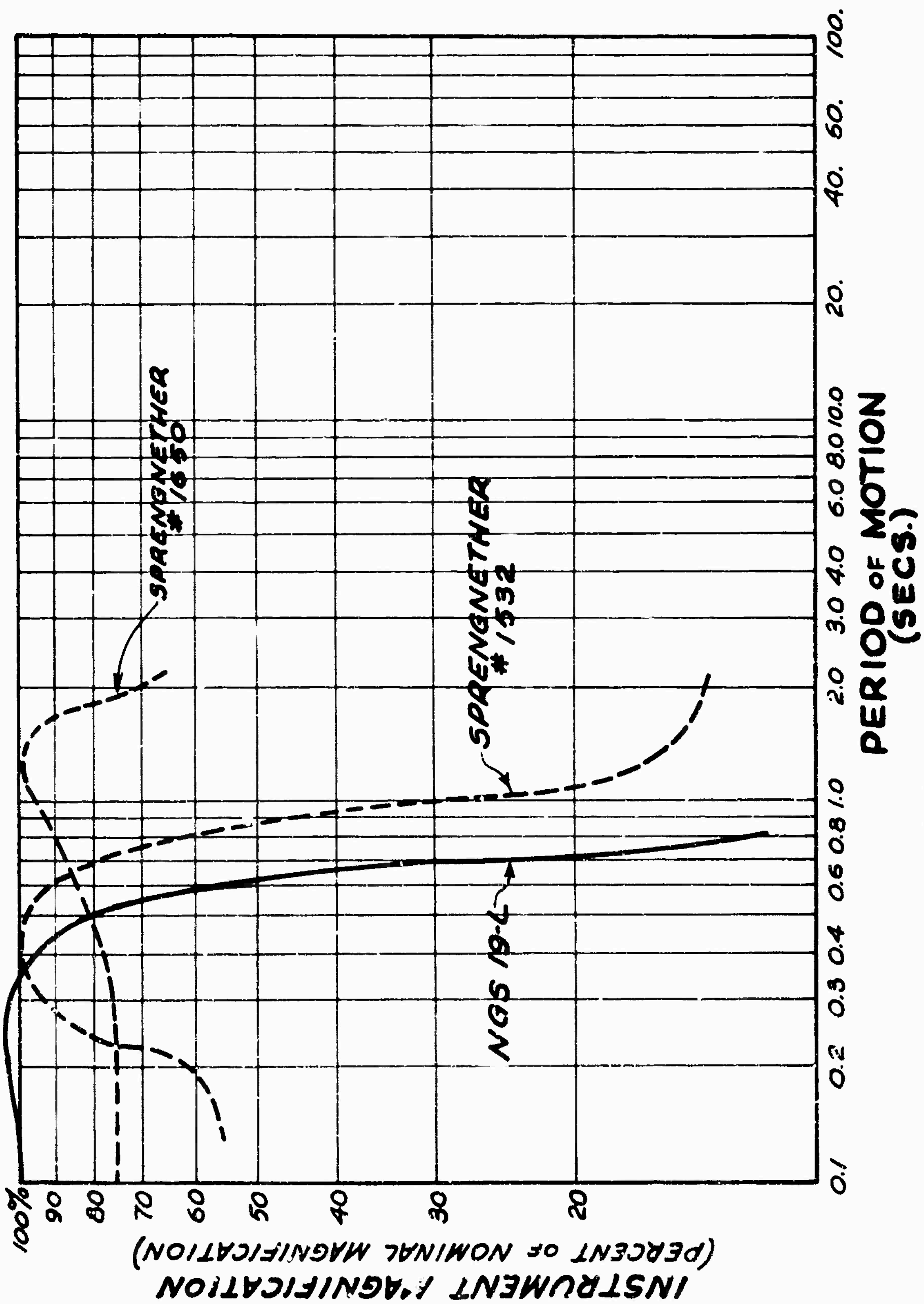


STAIRWELL VIEW-LOOKING NORTH

FIG. 4	JOHN A BLUME & ASSOCIATES RESEARCH DIVISION 612 HOWARD ST. S. F. CALIF.	WOMEN'S DORMITORY UNIVERSITY OF SOUTHERN MISSISSIPPI	BY: EGL CKD BY: KAT DATE: 5-1-65	FIG 4.



JOHN A BLUME & ASSOCIATES RESEARCH DIVISION 612 HOWARD ST. S.F. CALIF.	TCC & DIB MISSISSIPPI GULF REFINERY INSTRUMENT ARRANGEMENT	BY: ESL CKD BY: KAT DATE: 3-1-65	FIG 5



INSTRUMENT RESPONSE

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FIG. 6

FIG. 6

TECHNICAL AND SAFETY PROGRAM REPORTS SCHEDULED FOR ISSUANCE
BY AGENCIES PARTICIPATING IN PROJECT DRIBBLE

SAFETY REPORTS

Agency	Report No.	Subject or Title
USWB	VUF-1020	Meteorological Documentation and Radiation Protection
USPHS	VUF-1021	Final Report of Off-site Surveillance
USBM	VUF-1022	Pre and Post-Shot Safety Inspection of Oil and Gas Facilities Near Project Dribble
USGS	VUF-1023	Analysis of Geohydrology of Tatum Salt Dome
USGS	VUF-1024	Analysis of Aquifer Response
REECo	VUF-1025	On-Site Health and Safety Report
RFB, Inc.	VUF-1026	Analysis of Dribble Data on Ground Motion and Containment - Safety Program
H-NSC	VUF-1027	Ground Water Supply
FAA	VUF-1028	Federal Aviation Agency Airspace Advisory
H&N	VUF-1029	Summary of Pre and Post-Shot Structural Survey Reports
JAB	VUF-1030	Structural Response of Residential-Type Test Structures in Close Proximity to an Underground Nuclear Detonation
JAB	VUF-1031	Structural Response of Tall Industrial and Residential Structures to an Underground Nuclear Detonation.

NOTE: The Seismic Safety data will be included in the USC&GS Technical Report VUF-3014

TECHNICAL REPORTS

Agency	Report No.	Subject or Title
SL	VUF-3012	Free-Field Particle Motions from a Nuclear Explosion in Salt - Part I
SRI	VUF-3013	Free-Field Particle Motions from a Nuclear Explosion in Salt - Part II
USC&GS	VUF-3014	Earth Vibration from a Nuclear Explosion in a Salt Dome
UED	VUF-3015	Compressional Velocity and Distance Measurements in a Salt Dome

LRL	VUF-3016	Design and Operation of a Chemical Processing Plant for Controlled Release of a Radioactive Gas from the Cavity of a Nuclear Explosion in Salt
LRL	PNE-3002 *	Response of Test Structures to Ground Motion from an Underground Nuclear Explosion
SRI	VUF-3017	Feasibility of Cavity Pressure and Temperature Measurements for a Decoupled Nuclear Explosion
LRL	VUF-3018	Background Engineering Data and Summary of Instrumentation for a Nuclear Test in Salt
WES	VUF-3019	Laboratory Design and Analyses and Field Control of Grouting Mixtures Employed at a Nuclear Test in Salt
LRL	VUF-3020	Geology and Physical and Chemical Properties of the Site for a Nuclear Explosion in Salt
EG&G	VUF-3021	Timing and Firing

* This report number was assigned by SAN

In addition to the reports listed above as scheduled for issuance by the Project DRIBBLE test organization, a number of papers covering interpretation of the SALMON data are to be submitted to the American Geophysical Union for publication. As of February 1, 1965, the list of these papers consists of the following:

Title	Author(s)	Agency(s)
Shock Wave Calculations of Salmon	L. A. Rogers	LRL
Nuclear Decoupling, Full and Partial	D. W. Patterson	LRL
Calculation of P-Wave Amplitudes for Salmon	D. L. Springer and W. D. Hurdlow	LRL
Travel Times and Amplitudes of Salmon Explosion	J. N. Jordan W. V. Mickey W. Helterbran	USC&GS AFTAC UED
Detection, Analysis and Interpretation of Teleseismic Signals from the Salmon Event	A. Archambeau and E. A. Flinn	SDC
Epicenter Locations of Salmon Event	E. Herrin and J. Taggart	SMU USC&GS
The Post-Explosion Environment Resulting from the Salmon Event	D. E. Rawson and S. M. Hansen	LRL
Measurements of the Crustal Structure in Mississippi	D. H. Warren J. H. Healy W. H. Jackson	USGS

All but the last paper in the above list will be read at the annual meeting of the American Geophysical Union in April 1965.

LIST OF ABBREVIATIONS FOR TECHNICAL AGENCIES

BR LTD	Barringer Research Limited Rexdale, Ontario, Canada
ERDL	Engineering Research Development Laboratory Fort Belvoir, Virginia
FAA	Federal Aviation Agency Los Angeles, California
GIMRADA	U. S. Army Geodesy, Intelligence and Mapping Research and Development Agency Fort Belvior, Virginia
H-NSC	Hazleton-Nuclear Science Corporation Palo Alto, California
H&N. INC	Holmes & Narver, Inc. Los Angeles, California Las Vegas, Nevada
II	Isotopes, Inc. Westwood, New Jersey
ITEK	Itek Corporation Palo Alto, California
JAB	John A. Blume & Associates Research Division San Francisco, California
LRL	Lawrence Radiation Laboratory Livermore, California
NRDL	U. S. Naval Radiological Defense Laboratory San Francisco, California
REECo	Reynolds Electrical & Engineering Co., Inc. Las Vegas, Nevada
RFB, INC.	R. F. Beers, Inc. Alexandria, Virginia
SDC	Seismic Data Center Alexandria, Virginia
EG&G	Edgerton, Germeshausen & Grier, Inc. Las Vegas, Nevada
SL	Sandia Laboratory Albuquerque, New Mexico
SMU	Southern Methodist University Dallas, Texas
SRI	Stanford Research Institute Menlo Park, California
TI	Texas Instruments, Inc. Dallas, Texas
UA	United Aircraft El Segundo, California
UED	United Electro Dynamics, Inc. Pasadena, California
USBM	U. S. Bureau of Mines Washington, 25, D. C.
USC&GS	U. S. Coast and Geodetic Survey Las Vegas, Nevada
USGS	U. S. Geologic Survey Denver, Colorado
USPHS	U. S. Public Health Service Las Vegas, Nevada
USWB	U. S. Weather Bureau Las Vegas, Nevada